Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

Depiction of the methodological approaches to calculate the cost of electricity generation used in the scientific background reports serving as a basis for the Renewable Energy Sources Act (EEG) Progress Report 2007

Extract from

Renewable Energy Sources Act (EEG)

Progress Report 2007

- Chapter 15.1 -

pursuant to Article 20 of the Act

to be submitted to the German Bundestag

by

**the Federal Ministry for the Environment,
Nature Conservation and Nuclear Safety (BMU)**

in agreement with

the Federal Ministry of Food, Agriculture and Consumer Protection

and

the Federal Ministry of Economics and Technology

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1 Overview of the methodologies used in the studies forming the basis of the Progress Report 2007

1.1 Studies commissioned by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) [1]

In a complex system such as that constituted by the full spectrum of renewable-generated electricity, the impacts of the Renewable Energy Sources Act can only be subjected to transparent and comparative analysis – and policy recommendations developed on that basis – if a joint analytical framework is applied. This requires the use of representative, practice-oriented reference systems, e.g. to determine the structure and development of electricity production costs. In order to create a viable data basis for this purpose, comprehensive surveys were carried out among plant operators, which were then compared with published cost data and empirical values from project partners. The plants' average electricity production costs are calculated by means of the usual dynamic investment calculation [2], so that using the selected approach, an overview can be gained of the average annual costs across the entire period under review. The direct comparability with the remuneration rates payable under the EEG is then obtained by means of differentiation according to remuneration categories, and the imputed operating life of the plants according to the specific remuneration period. The interest rate chosen for the purposes of the calculation, based on the interest rates weighted for the proportions of equity capital and borrowed capital used in the funding of the plants, is set at a nominal basic value of 8%. The specific characteristics in the individual renewables sectors necessitate the adaptation of the parameters in some cases, and this is shown in the graphic depiction of the electricity production costs. The definition of the electricity production costs at today's price (reference year 2006), and the discounting of future EEG remuneration rates, are based on an inflation rate of 2% p.a. In the graphic overview, the priority is to set the nominal electricity production costs against the nominal remuneration rates; however, in the interests of transparency, the real electricity production costs and real remuneration rates are also shown.

Similarly, to calculate the environmental effects, sector-specific emission factors are used for CO_2 and the "classic" air pollutants, and extrapolated along the time axis [3]. In this context, a distinction must be made between direct and total emissions. Total emissions include indirect emissions arising from upstream process chains such as plant manufacture and the fuel supply. In relation to the use of renewable energies, however, indirect emissions have relatively little significance in terms of their environmental impacts. Furthermore, it is also very difficult to calculate the indirect emissions due to the complex correlations involved. Against this background, they will only be taken into account in exceptional cases where relevant.

A key factor when calculating the environmental effects is the reduction of CO_2 emissions achieved through the use of renewables. In the electricity sector, the expansion of renewables will progressively replace electricity generated from fossil-fuel power stations (especially coal-fired power stations), reducing CO_2 emissions accordingly. The Working Group on Renewable Energy Statistics (AGEE-Stat) has identified various emission factors here based on research findings. For example, in 2006, CO_2 emissions were reduced by around 922 g for every 1 kWh of conventional electricity substituted by renewables. Every 1 kWh of fossil-generated heat replaced by renewable-generated heat cut CO_2 emissions by 232 g in 2006, while every 1 kWh of fossil fuel substituted by renewables cut around 319 g of CO_2.

While resource conservation and climate protection were already key environmental goals in the 2000 Renewable Energy Sources Act, the new EEG, which came into force in 2004, contains specific provisions on nature conservation and environmental protection. The process for the environmental evaluation of the benefits of renewables use for nature and landscape as set out in Article 20 (1) of the Renewable Energy Sources Act is shown in Fig. 1-1. The environmental objectives defined in the EEG are the starting point; these generally relate to the desired environmental effects to be supported or achieved through renewables expansion. In many cases, however, they cannot be achieved directly and exclusively through the EEG, but are influenced by other instruments, such as those applied in the licensing of plants or the cultivation of biomass. Account has been taken of this in the analysis.

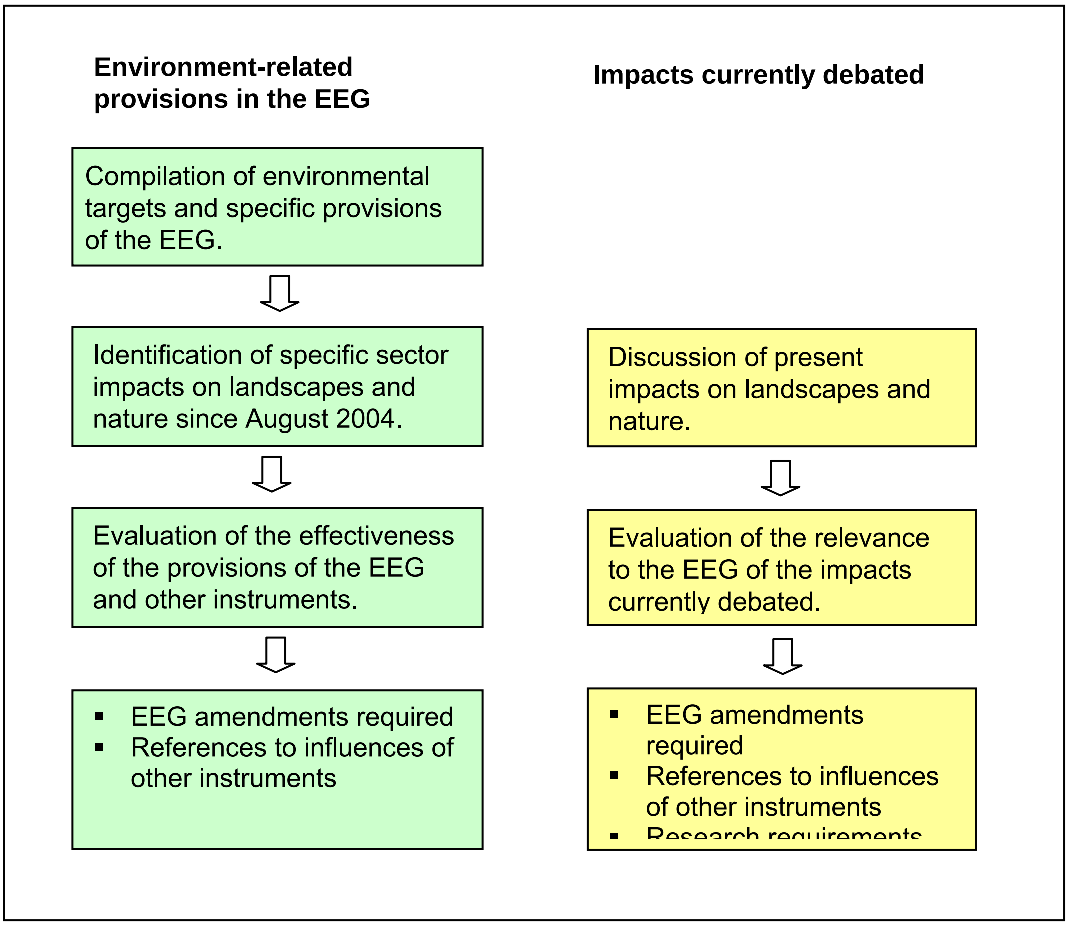

Figure 1-1: Process of environmental evaluation [1]

1.1.1 Methodology used for model calculations

To calculate the electricity production costs, an investment calculation using the annuity method is carried out for the various renewables sectors, with the exception of wind power. The annuity method is a method of dynamic investment calculation. Using this procedure, one-off payments and periodic payments of varying amounts can be translated into constant, i.e. average annual payments. The annuity factor used here is a function of the imputed interest rate and the review period for the calculation, which allows varying payment times to be taken into account.
For wind power, on the other hand, the net present value method is used so that account can be taken of sector-specific characteristics, especially the large variations in the payment streams within the review period.
For its part, the annuity method is actually a further development of the net present value method, so the results are comparable despite the different methodology [2].

All costs are initially determined on a real basis, i.e. adjusted for inflation, and the reference year for the cost calculation is 2006. This allows a direct interpretation of the calculated costs as these can be compared directly with other values related to 2006. To verify the profitability of plants generating electricity from renewables, costs have to be set against the revenues. The EEG does not provide for inflation to be either considered or offset, so the remuneration rates are set at a nominal constant value. The electricity production costs constitute an average value as they are determined on an imputed basis by means of the annuity method over an imputed calculation period (remuneration period according to the EEG). In order to compare electricity production costs (for the reference year 2006) and the remuneration rates according to the EEG for commissioning in 2006, the electricity production costs determined on a real basis have to be translated into nominal values by applying a nominal inflation rate of 2% p.a. This allows the calculated average nominal costs to be compared directly with the EEG remuneration rates.
However, the nominal remuneration rates are exposed to inflation across the entire period under review and therefore decline in real terms. Therefore, to avoid misunderstandings and misinterpretations, the annual inflation rate is also taken into account when calculating the real remuneration rates. This allows both the nominal remuneration rates to be compared with the nominal electricity production costs and the real electricity production costs to be compared with the real remuneration rates.

1.1.2 Input data used

To calculate the electricity production costs, representative, practice-oriented model applications falling within the EEG's scope of application were defined. In order to define the model cases, based on the plants currently in operation, the main types of facilities anticipated in new plants were determined, which were essentially differentiated by

- the plant's output for hydropower, landfill, mine and sewage gas, biomass, geothermal and photovoltaics (in each case, the various capacity classes capture the remuneration steps),
- the location for wind energy (e.g. offshore, onshore etc.) and photovoltaics (roof-mounted/freestanding systems etc.),
- the inputs / fuels used for solid, gaseous and liquid biomass and for landfill, mine and sewage gas (e.g. logging residues or wood waste in the case of solid bioenergy carriers, etc.),
- and, if appropriate, the technologies used (conventional technology, innovative technology such as Organic Rankine Cycle (ORC) etc.).

A technical reference is specified and calculated for each model case. This is done on a representative basis, i.e. by establishing typical values and boundary conditions. Empirical data from project partners, information from operator surveys and literature and results from other BMU studies are applied to establish the technical parameters and cost values (i.e. investment costs, costs for input materials, other operating costs, and, where appropriate, returns from heat supplied).

Investments

The investment costs include all the costs incurred in producing a complete plant that is ready for commissioning, including additional costs for planning, approvals, interest during construction etc.:

- Investment costs for
  - Machinery,
  - Electrical and control systems,
  - Construction (buildings, site installations etc.),
  - Connection to the infrastructure (grid connection including transformers, water supply, wastewater management etc.).

- Related costs for
  - Consultants, planning (including owner's own contribution), obtaining approvals, monitoring assembly, construction and commissioning,
  - Raising capital and funding, including interest during construction.

Operating costs

The following principal operating costs are incurred in the operation of renewable-generated electricity plants:

- Fuel costs in the case of biomass, mine, landfill and sewage gas,
- Service costs (maintenance and repairs),
- Personnel costs for technical plant operation,
- Insurance, administrative and leasing costs,
- Other variable costs for supplies (e. g. additional water, lubricating oil, dosing equipment for water treatment etc.), as well as to cover the plant's own electricity requirement and disposal of residual materials.

The operating costs used during this study should (with the exception of the maintenance costs for wind energy plants, see below) all be seen as mean values over the plant's operating life. This means that real, constant values are applied each year, which only rise with the general price increase rate over the plant's operating life. Admittedly, experience shows that individual operating costs, especially for maintenance, service and repairs, vary from operating year to operating year. However, this effect cannot be sufficiently quantified and is therefore not taken into account. The exception here is the maintenance costs for wind energy plants; these costs rise significantly in the second half of the plant's operating life due to the requirement for replacement investments, and this is reflected in the calculations.

Table 1-1 below contains a summary of the basic data and parameters used for the profitability calculations, and the selected cost estimates for the individual renewables sectors.

Table 1-1: Summary of the basic data and parameters used for profitability calculations [1]

	Hydro-power	Biomass	Landfill, sewage and mine gas	Geo-thermal	Wind	Photo-voltaics
Imputed period under review	30 a / 15 a	20 a	Basic case: 20 a (6 a variant for landfill gas)	20 a	Basic case: 20 a (variant: 16 a)	20 a
Nominal composite interest rate	Small plants 7%/a Large-scale plants 8%/a		8%/a	8%/a	8%/a	Variation within sector 5 - 8%/a
Inflation rate	2%/a					
Remuneration for heat (for CHP; ex-plant)	Basic case: € 25 /MWh (Variation within sector €10 - 40 /MWh)					
Specialist personnel costs	€ 50 T per person-year					
Equivalent operating hours at full capacity of electricity-led plants	Dependent on degree of utilisation	7,700 h/a	Landfill gas 7,000 h/a, sewage/mine gas 7,700 h/a	7,700 h/a	Dependent on conditions at location	
Equivalent operating hours at full capacity of heat-led plants	-	Dependent on model case	-	-	-	-

1.1.3 Treatment of revenues

When calculating electricity generation costs for plants that generate both heat and electricity, the total costs per annum should be split between these two products. In the case of renewables, this is especially true for plants that use solid and liquid biomass, biogas, sewage gas, landfill and mine gas. In such cases, therefore, the "residual costs of electricity generation" are calculated by deducting the heat payments from the total costs to receive the actual costs attributed to electricity as a product.

1.1.4 Treatment of investment cost subsidies

The calculations do not take account of support measures such as investment cost subsidies, for example.

1.1.5 Interest on capital employed and for inflation

An imputed review period is used as a basis for all the models, which corresponds to the values for the duration of the remuneration commitment established in Article 12 (3) of the EEG (20, 30 or 15 calendar years plus the year of commissioning).
Two or three different values – primarily depending on the plant's output – are applied to produce the nominal, imputed composite interest rate (without tax effects), in order to obtain maximum comparability of results and also to take account of the real circumstances. Thus, for example, a lower composite interest rate is normally applied in the case of small plants constructed by private operators than for large-scale plants. This is because the smaller

operators usually have a higher proportion of borrowed capital, lower-interest loans and usually lower profit expectations.
A profit based on the equity capital employed is incorporated into the calculations by selecting an appropriate equity capital interest rate.
All costs are initially determined on a real basis, i.e. adjusted for inflation, and the reference year for the costs is 2006. This allows a direct interpretation of the calculated costs as these can be compared directly with other values related to 2006. The costs are set against the remuneration rates applicable for commissioning in 2006 pursuant to the EEG. As these are nominal, constant values, i.e. are declining in real terms (taking account of the price increase rate), the nominal values are calculated and portrayed along with the real electricity generation costs.

1.1.6 Tax charges and benefits

As in similar surveys, taxes on transactions (turnover or land transfer taxes) and revenue-related taxes (income taxes) are not included in the model calculations carried out in this study, i.e. a pre-tax calculation will be used.
This procedure was chosen as the estimations of the (individual and significantly varying) rates of taxation which would otherwise be required would give rise to a potentially substantial source of errors. Ascertaining the precise profit-related taxes imposed requires the production of annual accounts and thus entails a detailed business assessment of each investment.

1.2 Studies commissioned by the Federal Ministry of Economics and Technology (BMWi) [4]

1.2.1 Methodology for model calculations

A standard process is used for all model calculations. This is a calculation model developed at the IE institute for the profitability calculations of electricity generation plants. The process used constitutes an annuity method and corresponds to the VDI 2067 standard in combination with the VDI 6025 standard. This allows all input data across all systems to be uniformly considered in the study.

1.2.2 Input data used

The comparability of model results depends primarily on the quality of the input data. In addition to the statements made in Chapter 2 (Overview of the Development of Renewable Energies in Germany; EEG Progress Report 2007), further research was carried out in order to obtain comparable input data for all energy carriers. The selection of input data is based partly on data from ongoing IE projects and partly on literature sources. The sources chosen here are those that, on the one hand, supplied sufficiently precise information on the individual items related to investment and operating costs, and on the other hand, provided plausible values compared to other sources (to avoid anomalies).
The sources used are shown individually in the relevant sub-sections to ensure a high level of transparency.
Electricity production costs are calculated for practice-oriented model cases and a technical reference is specified for each case. Values and parameters typical for the sector are used as a basis here. However, in specific individual cases, these parameters, and therefore also the profitability of the plants, can deviate significantly from the model cases examined in this study.

All model cases are assumed to be freestanding, newly constructed plants on greenfield sites with the potential to be connected to existing infrastructure (public electricity supply grid, water supply, waste disposal systems etc). Site procurement costs are not taken into account, nor are additional technical facilities such as peak load boilers to cover peaks in heat demand. Any additional costs for heat distribution are also not taken into account. This is permissible as a value is fixed for achievable heat remuneration which is understood as ex-plant (i.e. excluding heat distribution) and takes no account of peaks in demand (for which comparatively high remuneration can be achieved) [5]. An exception is made in the case of hydropower where account is also taken of the repowering of old plants along with the construction of new plants. This is appropriate as only very few plants have been newly constructed in the last 10 years. The majority of plants connected to the network have been old plants that have either been repowered or modernised. These incur significantly lower investment costs.

All the costs and prices used are average values and are based on empirical values, recommended price offers from plant manufacturers or publicly accessible statistics or literature that has been analysed in the course of this study and checked for plausibility. Own data surveys completed during ongoing projects and IE publications were also used. It must be noted that the cost estimates selected are inevitably exposed to a fluctuation margin and that significant deviations are possible in specific cases. For example, investment costs in particular are dependent on location. Operating and consumption-related costs are taken as constant mean values across the period of review, which are only exposed to the price increase rate.

In the following section, the cost groups examined in this study (in line with the VDI 2067 standard) and their input parameters are explained in more detail. Figure 1-2 gives an overall view of the methodology for calculating electricity production costs.

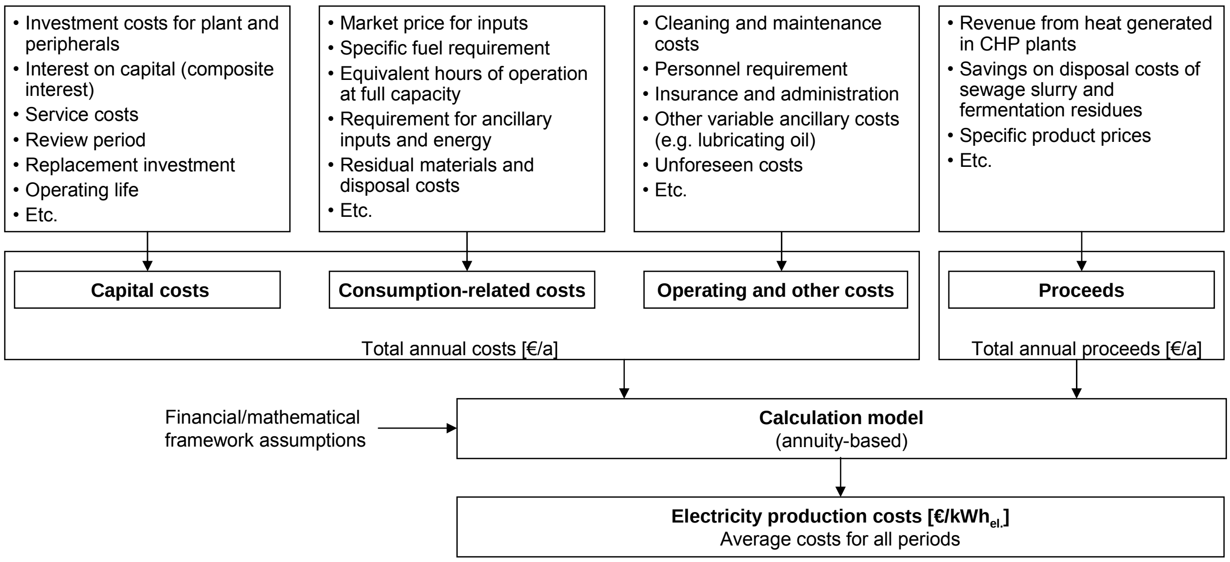

Figure 1-2: Methodology and input variables for calculating electricity production costs

- **Capital costs:**

  Capital costs comprise investment costs and service costs. No account is taken of investment subsidies or other support measures (see Section 4.1.5; EEG Progress Report 2007).

  − The investment costs applied in the calculation include all necessary costs (structural and technical facilities, supply and disposal lines and network connections) required to produce a complete plant that is ready for commissioning, including ancillary costs (planning, approvals, raising capital and funding etc.).

  − Service costs are put at 1% of the specific investment costs for buildings and built structures and 2% for engineering systems. Furthermore, replacement investments within the relevant review period (generally 20 years) are included with reference to the individual operating life[18] of structural and technical components.

- **Consumption-related costs:**

  These are particularly significant in the case of bioenergy plants. The following costs are incurred:
  - Fuel and/or substrate costs, unless they can be provided free of charge within the operation (e.g. saw mill residue or liquid manure):
    - Logging residues € 50/t (calorific value: 3.30 kWh/kg)
    - Wood from landscape management €10/t (calorific value: 2.2 kWh/kg)
    - Wood waste: €17/t (calorific value: 3.42 kWh/kg) assumed in the case of co-firing with wood waste (the wood waste-AIV fraction is generally not more than 10%); the prices for pure wood waste fluctuate between € 0-30/t
    - Rapeseed oil €0.65/l and palm oil € 0.45/l (calorific value: 9.6 kWh/l, prices ex-plant)
    - Maize silage € 25/t (biogas yield: 198 m^3/t_{solid})
    - Organic waste (biogas yield: 110 m^3/t_{solid}), see proceeds

  - The plant's own electricity requirement: taken from the public supply grid depending on the amount of energy used – set at 6 to 12 ct/kWh
  - Use of ancillary inputs (e. g. engine or heating oil, additional equipment for flue gas treatment, water treatment)
  - Disposal costs of residual materials (e. g. ash € 50/t[19])

- **Operating costs:**

  The following costs are considered as operating costs:
  - Maintenance and cleaning costs: generally included as 1% of investment costs or as a lump sum cost for full maintenance contracts (e. g. in the case of small-scale CHP units fired with plant oil)
  - Personnel costs for technical plant operation: the figure of €50,000 per year and person is estimated for one full-time employee; the number of employees is set on the basis of the research carried out (depending on the technology being deployed in the plant, the installed capacity and, if applicable, the cost of fuel preparation, for example). Where lower-paid workers are used (in the biomass area), their wages are converted accordingly.

- **Other costs:**

  Insurance and administrative costs along with other variable ancillary costs (e.g. lubricating oil, dosing equipment for water treatment, lump sums to cover costs for unforeseeable repairs) are included as "other costs" in the review. In the case of bioenergy plants, 1% of the investment costs is imputed for insurance with a further 1% for variable plant costs; these values are identified individually for the other technologies as well. One exception here is the organic waste fermentation plants where the other variable costs are put at 2.5%.

1.2.3 Treatment of proceeds

When calculating electricity generation costs for CHP plants, the total costs per annum are to be split between the two products. In such cases, therefore, the "residual costs of electricity generation" are calculated, where the heat remuneration is deducted from the total costs to elicit the actual/resulting costs of electricity generation (i.e. taking account of the proceeds/credits for heat supplied). Finally, for illustration purposes, the nominal electricity production costs (i.e. taking account of the inflation rate) are set against the remuneration rates laid down in the EEG, as the wording of the law states that these remain nominally constant (i.e. decline in real terms) over a period of 20 years for the plants concerned.
Proceeds: In the case of CHP plants, remuneration is given for the heat used externally (i.e. excluding the plant's own heat requirements) and this is deducted from the total costs to elicit the actual costs incurred for electricity as a product.

Remuneration for heat supplied corresponds to:

- where the heat is used to meet the plant operator's own heat requirements: the costs the operator would incur for alternative fossil-generated heat;
- where third parties are supplied or heat is fed into existing district or local heat networks: the average achievable market prices (set here at €25/MWh).

Furthermore, where organic wastes are fermented disposal credits can be applied. In this study, credits of €60 /t_{solid} of organic waste were applied, which included the potential commercial sale of the fermentation residue as compost. Where electricity is produced from sewage gas, the disposal costs that were avoided are regarded as proceeds and presented separately.

1.2.4 Treatment of investment cost subsidies

No investment cost subsidies are available for building renewable-generated electricity plants that can feed electricity into the grid in accordance with the EEG. Research has shown, however, that potential plant operators can obtain investment cost subsidies in individual cases, but there are regional differences here. This happens when, for example, individual *Länder* take a pioneering role in the use of certain innovative technologies (e.g. biogas plant feeding into the gas network). Subsidised training is also offered to future bioenergy plant operators, and completion of these training courses has a positive impact on financial negotiations and therefore also on interest rates on borrowed capital. The above benefits, however, vary greatly from region to region and cannot be generalised in the type of general overview conducted in this study.
A review of the terms and conditions of the market incentive programme showed that the investment cost subsidies available only applied to plants of under 100 kW, which generally do not generate any electricity. Therefore none of the model cases defined meets the criteria for these investment cost subsidies. No investment cost subsidies are offered by the KfW banking group.

1.2.5 Interest on capital employed and for inflation

The comments made in the previous section notwithstanding, various low interest-rate programmes[20] are available from the *Kreditanstalt für Wiederaufbau* (KfW banking group) which can be considered here. Interest rates of between 3 and 7% are offered, mostly up to 5% depending on the overall risk, the profitability of the project, creditworthiness and proportion of equity capital. A composite interest rate of 5% has been assumed for all the model cases calculated in this study. Geothermal projects are subject to a composite interest rate of 7% as these are very high-risk projects for which KfW also charges a higher rate of interest.
The general price increase rate reflects inflation. A 1% inflation rate is assumed for capital costs and 2% for operating, consumption-related and other costs; these levels are recommended by VDI 2067. Real price increases (future market prices) are not included.

1.2.6 Tax charges and benefits

The calculation does not include any tax charges or benefits as the resultant estimations of the (individual and significantly varying) rates of taxation would give rise to a potentially substantial source of errors. All calculated production costs therefore portray the pre-tax operating results of the plants. Regardless of how the investor is subject to taxation at a later date (with or without depreciation or amortisation possibilities), operating results thus cannot be improved by special tax benefits or by offsetting profits and losses for tax purposes. In the best-case scenario, the calculated operating result is untaxed and retained in full, and in the worst-case scenario the profit achieved, from the perspective of the operator, is taxed at the full rate payable by the operator and therefore reduced.

In the wind power sector, opportunities for tax write-off have become an important factor in the investment decisions of many investors in recent years. In terms of the model cases calculated, this means that where favourable tax write-off opportunities are available, all or most of the operating result is retained as profit.

[1] Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) / Bosch & Partner GmbH / Deutsche Windguard GmbH / Fichtner GmbH & Co. KG / Gentechnische Vereinigung-Service GmbH / Institut für ZukunftsEnergieSysteme gGmbH (IZES) / Internationales Wirtschaftsforum Regenerative Energien / Wuppertal Institut für Umwelt, Klima, Energie GmbH (WI): Vorbereitung und Begleitung bei der Erstellung eines Erfahrungsberichtes gemäß § 20 EEG. Im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit. November 2007.

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